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Region VIII

**MEMORANDUM** DEC 20 2001

**SUBJECT:** Amphibole Mineral Fibers in Source Materials in Residential and Commercial Areas of Libby Pose an Imminent and Substantial Endangerment to Public Health

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## I PURPOSE

This memorandum presents the rationale for determination of imminent and substantial endangerment to public health from asbestos contamination in various types of source materials at residential and commercial areas in and around the community of Libby, Montana. With this memorandum, I confirm and extend a similar conclusion derived in two previous memoranda from my office to you (dated May 10, 2000, and July 9, 2001).

## II SUMMARY OF FINDINGS

1) Asbestos occurs in ore and processed vermiculite obtained from the Libby mine.

2) Asbestos fibers of the type that occur in vermiculite ore from the mine in Libby are hazardous to humans when inhaled.

3) Asbestos material fibers that are characteristic of those that occur in materials from the Libby mine are present in a variety of different source materials at residential and commercial locations in and around the community of Libby. Outdoor source materials include yard soil, garden soil, driveway material, and assorted mine waste materials, while indoor source materials include dust and vermiculite insulation.

4) Disturbance of asbestos-contaminated source materials by activities similar to those that are likely to be performed by area residents or workers can result in exposure to respirable asbestos fibers in air.

5) The concentrations of fibers in air generated by disturbance of source materials may exceed OSHA standards for acceptable occupational exposure, and estimated

excess cancer risks can exceed EPA's typical risk range (1E-04 to 1E-06) by an order of magnitude or more. There are several factors which suggest these risk estimates may be too low and that actual risks are even greater.

On this basis, I conclude that source materials such as soil and soil-like media, dust, and vermiculite insulation that contain friable asbestos minerals are a likely source of on-going release of hazardous fibers to indoor and/or outdoor air at multiple residences and commercial facilities in Libby. In light of clear biological evidence of human asbestos exposure in Libby and the associated increase in human risk, I recommend that EPA take appropriate steps to reduce or eliminate pathways of exposure to these source materials in order to protect area residents and workers.

## III BACKGROUND

A large deposit of vermiculite was discovered on Zonolite Mountain in the Rainy Creek Mining District of Lincoln County, Montana, in 1916 by E.N. Alley. Alley formed the Zonolite Company and began commercial production of vermiculite in 1921. Another company, the Vermiculite and Asbestos Company (later known as the Universal Insulation Company), operated on the same deposits (BOM 1953). W.R. Grace purchased the mining operations in 1963 and greatly increased production of vermiculite until 1990 when mining and milling of vermiculite ceased.

Vermiculite ore bodies on Zonolite Mountain contain amphibole asbestos at concentrations ranging up to nearly 100% in selected areas (Grace). Although early exploration and mining efforts by the Zonolite Company focused upon the commercial viability of fibrous amphibole deposits found on Zonolite Mountain (DOI 1928), no commercial production of asbestos from the Libby mine is reported. During early vermiculite mining operations, airborne concentrations of asbestos fibers at the mine exceeded 100 fibers per cubic centimeter (f/cc) in several job classifications (Amandus et al. 1987a,b, & c). Historical airborne fiber concentrations in the residential area of Libby also exceeded the present occupational Permissible Exposure Level (PEL) of 0.1 f/cc established by OSHA (1994) (MRI 1982; Eschenbach deposition). This exposure limit is recognized as being associated with significant risk (3.4 additional asbestos-related cancers per 1000 individuals as per OSHA estimates) to workers, and risks to residents could be even higher.

Residual fiber contamination from the subject facilities continues to present potential exposure to workers, residents, and visitors at these facilities, but is presently being addressed under removal authorities provided in the Comprehensive Environmental Response Compensation and Liability Act Section 104 (CERCLA or Superfund). These actions by the U.S. Environmental Protection Agency Region 8 office in Denver, CO began on November 22, 1999 and continue today. The investigative team is working closely with Local, State, and other Federal Agencies to determine the nature and extent of mineral fiber contamination throughout Libby, and to take appropriate action to protect the health of current residents and workers.

## IV ENDANGERMENT RATIONALE

The rationale for determination of imminent and substantial endangerment from asbestos-contaminated source materials in residential and commercial areas of Libby is five-fold:

1) Asbestos fibers occur in ore and processed vermiculite from the Libby mine site.

2) Asbestos fibers from the Libby mine site are hazardous to humans as evidenced by the occurrence of asbestos-related disease in area workers and residents. Workers exposed to asbestos fibers at the Libby mine site have been shown to experience clear and significant increases in the incidence of asbestos-related conditions, including asbestosis, lung cancer and mesothelioma. Asbestos-related lung diseases have also been observed in area residents with no direct occupational exposures, including family members of mine workers, and even in those with no known association with the vermiculite mining or processing;

3) Asbestos fibers can be detected in several types of source materials (yard soil, garden soil, driveway material, waste piles, indoor dust, vermiculite insulation) at multiple locations in and around the residential and commercial area of Libby. These contaminated materials constitute a potential source of asbestos exposure to area residents and workers;

4) Asbestos fibers in contaminated source materials may be released into air by a variety of activities similar to those that area residents or workers may engage in under normal living or working conditions. This demonstrates that a complete exposure pathway exists by which asbestos-contaminated source materials may cause inhalation exposure of area residents and workers;

5) The concentrations of asbestos fibers that occur in air following disturbance of source materials may reach levels of potential human health concern, as evidenced by a) exceedences of OSHA standards for the protection of workers following disturbance of vermiculite material, and b) exceedences of EPA's normal risk range (1E-04 to 1E-06) for acceptable lifetime excess cancer risks for exposed humans. Actual risks may be even greater than estimated.

Summaries of the evidence supporting each of these elements of rationale are presented below.

### 1. Asbestos occurs in ore and vermiculite from the Libby mine

In order to gain a reliable understanding of the mineralogical characteristics of asbestos material associated with the Libby mine, the United States Geological Survey (USGS) collected 30 samples of asbestos-enriched ore material from the mine (USGS, 2001). Analysis of multiple asbestos fibers in these samples was performed by electron dispersive spectroscopy (EDS) and electron diffraction in order to determine the elemental composition and the associated mineralogical class. The results are shown in Figure 1. As seen, fibers obtained from the mine span a range of over-lapping mineral types, including actinolite, tremolite, winchite, and richterite, with lower amounts of magnesio-arfedsonite and edenite/ferro-edenite. For the purposes of this memo, fibers included in the group above are referred to as "Libby-class amphiboles".

## 2. Libby Asbestos Fibers Are Hazardous to Human Health (Hazard Assessment)

Evidence of the adverse effects from exposure to asbestos fibers associated with the vermiculite ore body on Zonolite Mountain is abundant. During the 1980s, MacDonald et al. (1986a,b), and Amandus et al. (1987a,b,c) conducted investigations of asbestos exposure, and the morbidity and mortality of workers involved in various aspects of vermiculite mining, milling and refining processes in Libby, MT. These investigations found that workers had significantly increased occurrence of asbestosis, lung cancer, mesothelioma, and asbestos-related pleural disease associated with exposure to the vermiculite. Additionally, increased asbestos-related lung abnormalities were found among workers at an expansion plant in Marysville, Ohio, that were exposed to vermiculite from the Libby mine, Lockey et al. (1984).

Since the cessation of vermiculite mining and processing operations in Libby, local physicians and nearby pulmonary specialists have continued to identify individuals suffering from asbestosis, lung cancer and mesothelioma as a result of exposure to asbestos mineral fibers. One board-certified pulmonologist has reportedly seen over 150 cases of asbestos-related disease from the Libby area (Whitehouse 2000). In addition to former mine workers, this physician reported striking findings of asbestos-related disease among household contacts of former workers and among area residents with no identifiable connection to the former mine or processing activities. Some of those area residents with asbestos-related disease and no connection to the mining operations were reportedly exposed to asbestos through activities such as playing in open piles of vermiculite ores and wastes near recreational parks, gardening in soil containing vermiculite, and contact with vermiculite insulation in the home. Reports by area physicians are supported by recent morbidity and mortality assessments of Libby residents conducted by the Agency for Toxic Substances and Disease Registry (ATSDR). A mortality study for Libby area residents from 1979 to 1998 found increased rates of asbestosis (40-60 times higher than the normal background rate for the United States) and mesothelioma (ATSDR 2000). Additionally, ATSDR, working in cooperation with USEPA Region 8, U.S. Public Health Service, the State of Montana, and Lincoln County, has performed an extensive exposure and medical testing program involving nearly 6000 individuals that worked or lived in Libby for at least six months prior to 1991. Preliminary analysis of the data indicate that the crude odds ratio for the occurrence of pleural abnormalities is significantly elevated for individuals who were workers at the mine, and also for a variety of other non-occupational exposure pathways involving contact with vermiculite. Individuals with multiple exposure pathways to vermiculite or mine materials had higher disease incidence that those with no known exposure. Asbestos-associated radiologic abnormalities, similar to those observed among medical testing participants in Libby, have been shown in other populations to be associated with significant progression of disease, morbidity, and mortality (Miller 1983, Cookson 1986, Rosenstock 1991, Erlich 1992, Hillerdal 1997).

## 3. Asbestos Fibers Occur in Several Types of Source Material in Residential/Commercial Areas

For approximately 2 years, EPA has been collecting samples of asbestos material associated with former mining and milling in the Libby, MT environment. This has included collection numerous types of potential source materials (outdoor yard soil, garden soils, indoor dust, vermiculite insulation, various types of waste piles, etc) as well as numerous air samples. Examination and evaluation of soil-like materials and bulk insulation samples was performed using polarized light microscopy (PLM), while samples of dust were evaluated by transmission electron microscopy (TEM), as detailed in the *Sampling and Quality Assurance Project Plan (Revision 1) for Libby, MT* (USEPA 2000). Initial sample collection efforts (referred to as Phase 1) focused mainly on areas formerly associated with mining and processing operations (the export plant, the screening plant, Rainy Creek Road, etc.), but also included samples collected from the residential and commercial areas of Libby. The second round of sampling (referred to as Phase 2) focused primarily on asbestos levels in the residential setting, with special attention on the effect of disturbance of source materials on asbestos levels in air.

The following sections summarize available data on the range of concentration values of Libby-type asbestos in samples of potential source materials (e.g., yard soil, garden soil, waste piles, driveway material, indoor dust, vermiculite insulation, etc.) at numerous locations in residential and light commercial areas of Libby. The data presented do not include measurements from former mine-related sites (e.g., the export facility, the screening facility, or Rainy Creek Road). Also, data from schools are not included, since they are not likely to be a good model for residential and commercial structures, and separate regulations exist for dealing with asbestos in schools. All data utilized in the following sections were based on a query of the Libby database performed on December 12, 2001, and all of the data from this query are available upon request.

*Soil-Like Media (Yard Soil, Garden Soil, Waste Piles, and Driveway Material)*

As noted above, samples of soil and related soil-like materials were analyzed for asbestos by PLM. Garden soils were grouped differently that yard soils since some garden soils might be amended with vermiculite even when the yard soil is not contaminated. Each sample was classified into one of the following groups:

| | |
|---|---|
| Non-Detect (ND) | Presence of asbestos could not be confirmed by PLM |
| Trace | Asbestos is present, but the amount is too low (less than about 1% asbestos by mass) to allow reliable quantification |
| Detect | Asbestos is present at a level (typically 1% by mass or higher) such that quantification by PLM is possible. |

Summary statistics for individual samples, grouped by medium, are presented below:

**Table 1: Summary Statistics for Soil Like Media (Grouped by Sample)**

| Source Medium | Total Number of Samples | Number of Samples With Result Specified | | | Range of Detects |
|---|---|---|---|---|---|
| | | ND | Trace | Detect | |
| Yard Soil | 832 | 610 | 200 | 22 | 1%-5% |
| Garden Soil | 183 | 96 | 80 | 7 | 1%-5% |
| Waste Piles | 12 | 1 | 1 | 10 | 1%-10% |
| Driveway material | 137 | 118 | 18 | 1 | 1% |
| All soil-like media | 1164 | 825 | 299 | 40 | 1%-10% |

As these data demonstrate, asbestos is detectable by PLM in about 29% (339 out of 1164) of the samples of soil and soil-like media have been collected from residential and commercial areas of Libby. Summary statistics for the maximum value detected at each of the individual residences or commercial buildings investigated are shown below:

**Table 2: Summary Statistics for Maximum Values Grouped by Location**

| Source Medium | Total Number of Locations | Number With Maximum Result Specified | | | Range of Max |
|---|---|---|---|---|---|
| | | ND | Trace | Detect | |
| Yard Soil | 258 | 139 | 106 | 13 | 1%-5% |
| Garden Soil | 109 | 43 | 59 | 7 | 1%-5% |
| Waste Piles | 3 | 1 | 0 | 2 | 8%-10% |
| Driveway | 94 | 77 | 16 | 1 | 1% |
| Any of the above | 263 | 101 | 141 | 21 | 1%-10% |

As indicated in table 2, of the total homes and commercial properties investigated, about 62% (162 out of 263) have detectable levels of asbestos present in one or more samples of an outdoor soil-like medium.

These findings support the conclusion that multiple locations exist where asbestos levels in outdoor soil-like media may serve as an on-going source of human exposure. Moreover, it is important to recognize that the PLM method has a relatively high detection limit for asbestos, and a non-detect by PLM is not equal to proof the sample is not contaminated with asbestos. To the contrary, other microscopic techniques (e.g., scanning electron microscopy) have shown that some soil samples that are below the limit of detection by PLM do contain high levels of asbestos fibers (see Weis 2000 for a scanning electron microscope image of asbestos fibers in a soil sample that was below the limit of detection by PLM, and Addison 1995). The EPA is working to develop scanning electron microscopy and other related methods for the analysis of fiber in soil, but the methods are not yet sufficiently refined to support quantitative estimates of fiber concentration.

*Vermiculite Insulation*

Samples of bulk vermiculite insulation were analyzed for asbestos by PLM, and each sample was classified into one of three groups, as described above. Detection frequencies and ranges of quantifiable concentrations in individual samples, grouped by medium, are summarized below:

**Table 3: Summary Statistic for Samples of Vermiculite Insulation**

| Grouped by | Total Number | Number With Result Specified | | | Range of Detects |
|---|---|---|---|---|---|
| | | ND | Trace | Detect | |
| Sample | 82 | 22 | 53 | 7 | 1%-5% |
| Location | 69 | 15 | 47 | 7 | 1%-5% |

As seen, asbestos fibers are detectable in about 60 of 82 (73%) samples of all vermiculite insulation, and in about 54 out of 69 (78%) of all locations tested. Concentration values range from trace (<1%) up to 5% by mass.

*Indoor Dust*

Analysis of indoor dust samples collected from residential locations or commercial buildings was performed using TEM in accord with the methods and counting rules specified in ISO 10312. In this procedure, individual asbestos structures are observed, and their size, shape, and mineral category are recorded. Because of this, there are several alternative ways in which the concentration of asbestos in the dust may be expressed. For the purposes of this memo, emphasis is placed on the concentration of fibers that are equivalent to those that would be detected using phase contrast microscopy (PCM), since this is the traditional method for measurement of asbestos fibers in air, and current methods for estimating risk from asbestos in air are based on the PCM method of quantification. PCM fibers are equal to or longer than 5 um, have an aspect ratio of at least 3:1, and are thick enough to be detected by PCM (about 0.25 um in diameter). Fibers observed under TEM that have these attributes are referred to as PCM-equivalents (PCME). Although PCM can not distinguish between asbestos fibers and non-asbestos fibers, this distinction is possible with TEM, so the PCME values derived from TEM analysis may be based either on all fibers, or on asbestos fibers only. In this report, PCME estimates based on all fibers (asbestos plus non-asbestos) are referred to as PCME-all and estimates based on Libby-type amphibole asbestos fibers only are referred to as PCME-asb. Because concentrations based on PCME-all are likely to over-estimate asbestos fiber concentrations in exposure situations such as the home where non-asbestos fibers are common, this value is not used in this memo and emphasis is placed on PCME-asb.

Detection frequencies and ranges of quantifiable concentrations in dust, grouped either by individual sample or by maximum at a property, are summarized below for both Phase 1 and Phase 2 samples:

**Table 4: Summary Statistics for Indoor Dust Samples**

| Grouped by | Data Set (a) | Total Number | PCME-asb | |
|---|---|---|---|---|
| | | | Detection Freq. | Range of Detects (s/cm$^2$) |
| Sample | Phase 1 | 258 | 30/258 | 20-22645 |
| | Phase 2 | 3 | 3/3 | 1011-3658 |
| Property (max value) | Phase 1 | 108 | 25/108 | 20-22645 |
| | Phase 2 | 3 | 3/3 | 1011-3658 |

(a) Results from the Phase 1 study are currently reported only as "binned" fiber counts (i.e., the number of fibers within certain size classes), while in Phase 2, data were reported on the size (length, width) of each individual fiber. Thus, for Phase 1 data, PCME fibers are estimated by summing the number of fibers in size bins that overlap the definition of PCM fibers, while for Phase 2, the number of PCM equivalent fibers can be calculated directly.

As seen, PCME-asb fibers are detected in 33 out of 261 (13%) of the dust samples collected , and in at least one sample at 28 out of 111 (25%) of all residential and commercial locations sampled. This indicates that there are multiple locations around Libby that are likely to contain asbestos fibers in indoor dust, and that this dust may serve as an on-going source of potential exposure for residents.

## 4. Disturbance of Contaminated Source Materials Can Release Fibers to Air

Asbestos fibers in soil or dust are not inherently hazardous to humans if left undisturbed. However, most soils and dusts are subject to disturbance, either now or in the future, by many different types of activities that are common for residents.

Information on the potential for release to air from each type of source material is summarized below. In all cases, the concentration values in air reported below are averages based on samples that were above the limit of detection. Air samples were normally analyzed by TEM and by PCM.

*Release from Waste Piles*

No studies have been performed in the residential/commercial area of Libby to quantify the release of asbestos from piles of vermiculite or other related mine waste materials, but studies performed during Phase 1 and subsequent remedial activities at these locations clearly demonstrate that disturbance of this type of material has the potential to release high levels of asbestos fibers into air. These results have been presented in my previous memo (Weis, 2001).

*Release from Driveway Material*

No studies have been performed in the residential area of Libby to quantify the release of asbestos from driveway material, but studies along Rainy Creek Road clearly demonstrate that disturbance of asbestos in roadways by vehicle traffic has the potential to release high levels of asbestos fibers into air. These results have been presented in my previous memo (Weis, 2001).

*Release from Garden Soil*

To date, only limited data are available on the release of fibers to air from disturbance of garden soil. As part of EPA's Phase 2 study, samples of personal air were collected by an individual engaged in rototilling a garden in Libby. These data are summarized below:

**Table 5: Concentration of Asbestos in Air Associated with Rototilling**

| Analytical Method | Mean Concentration of Detects (f/cc) | |
|---|---|---|
| | Personal | Stationary |
| PCM | 0.227 | 0.020 |
| TEM (PCME-asb) | 0.066 | 0.019 |

As seen, elevated levels of fibers are observable in both personal air samples and in nearby stationary air monitors during the rototilling activity. The increase is larger when measured by PCM than by TEM (PCME-asb), suggesting that some of the increase detected by PCM is non-asbestos in nature. The soil concentrations in this garden were measured in six samples by PLM. Four of the six samples analyzed were non-detects, and two samples detected trace amounts (less than 1% by mass) of asbestos. As noted above (see Table 1), other gardens in Libby may have asbestos concentrations up to 5%, suggesting releases at other gardens might be substantially greater.

*Release from Yard Soil*

At present, no data have been collected that specifically address the potential for disturbance-based release of asbestos fibers from yard soil to air. It is expected that release will not be extensive at locations that are grass-covered, but could be extensive at locations that have little or no vegetative cover. Some release might occur through processes such as wind erosion, but human disturbances are likely to be of greater concern, especially under conditions when the soil is dry. This might include walking or playing in sparsely vegetated areas, or disturbances of the soil from mechanical devices such as bikes, lawn mowers, etc.

This conclusion is strongly supported by the study of Addison (1995) who generated airborne dusts from a series of soils with varying levels of asbestos contaminations. The study concluded that ***"even the lowest bulk amphibole concentration tested (0.001%) was still capable of producing measurable airborne asbestos concentrations (greater than 0.01 fibers ml$^{-1}$)"***

*Release from Indoor Dust*

In order to obtain information on the potential for human activities to cause elevated asbestos levels in indoor air, EPA planned and performed a study referred to as Phase 2. The design of this investigation is presented in the *Phase 2 Sampling and Quality Assurance Project Plan (Revision 0) For Libby, Montana* (USEPA 2001). In brief, personal air monitors were used to measure the concentration of asbestos fibers in the breathing zone of people engaged in a series of scenarios that involved routine and special activities in the home, and stationary air monitors were used to measure to concentration in the general vicinity of the activities. The first two scenarios investigated in Phase 2 involved routine residential behaviors, as follows:

Scenario 1: Routine household activities
Scenario 2: Active cleaning activities (dusting, sweeping, vacuuming, etc.)

Results are summarized below.

**Table 6: Concentration of Asbestos in Air Associated with Household Activities**

| Scenario | Method | Type | Detection Frequency | Values for Detects (f/cc) | |
|---|---|---|---|---|---|
| | | | | Mean | Range |
| 1 (Routine activity) | PCM | Personal | 6/9 | 0.007 | 0.001-0.014 |
| | | Stationary | 19/20 | 0.006 | 0.002-0.012 |
| | PCME-asb | Personal | 2/5 | 0.035 | 0.023-0.048 |
| | | Stationary | 4/10 | 0.009 | 0.0003-0.036 |
| 2 (Active cleaning) | PCM | Personal | 37/46 | 0.112 | 0.014-1.017 |
| | | Stationary | 22/31 | 0.021 | 0.007-0.068 |
| | PCME-asb | Personal | 6/26 | 0.010 | 0.004-0.013 |
| | | Stationary | 3/17 | 0.008 | 0.007-0.010 |

As indicated above, routine residential activities (Scenario 1) resulted in a small increase in fibers in personal air compared to nearby stationary air monitors when measured by PCM, and a clearer increase when measured by TEM (PCME-asb). For Scenario 2 (active cleaning), a clear increase was observed by PCM, with a smaller increase for TEM (PCME-asb). These data indicate that routine human activities in the home are associated with inhalation exposure to asbestos fibers in air, and reveal that fiber counts based on PCM may not be reliable for evaluation of asbestos risks due to confounding by increased levels of non-asbestos fibers.

*Release from Vermiculite*

As part of the Phase 2 study, EPA collected data from personal and stationary air monitors in the immediate vicinity of people actively engaged in disturbing vermiculite insulation. This scenario (referred to as Scenario 3) was intended to assess exposures that might be experienced either by homeowners who engaged in activities in unfinished attic areas, or for contractors who might come into contact with vermiculite during repair or remodeling activities. The results are summarized below.

**Table 7: Concentration of Asbestos in Air Associated with Disturbance of Vermiculite**

| Sample Type | Analytical Method | Detection Frequency | Values for Detects (f/cc) | |
|---|---|---|---|---|
| | | | Mean | Range |
| Personal | PCM | 4/5 | 0.568 | 0.118-1.62 |
| | TEM (PCME-asb) | 5/5 | 0.309 | 0.042-1.057 |
| Stationary | PCM | 4/4 | 0.142 | 0.035-0.324 |
| | TEM (PCME-asb) | 3/4 | 0.309 | 0.023-0.789 |

As seen, active disturbance of vermiculite results in very high concentrations of fibers as measured by both PCM and TEM (PCME-asb).

These findings are consistent with previous studies conducted by W.R. Grace (see Figure 2). These “drop tests” demonstrated that fiber concentrations in air resulting from pouring vermiculite insulation onto the floor under controlled conditions can be extremely high even when bulk concentrations in the vermiculite are less than 1% (Grace 1976).

These results clearly indicate that vermiculite insulation in homes or commercial buildings is a substantial reservoir of asbestos-contaminated source material that may lead to on-going exposure of area residents and workers.

*Summary of Evidence for Disturbance-Based Release*

Taken together, the data summarized above (including EPA's Phase 1 studies from the screening plant, export plant, and Rainy Creek Road, EPA's Phase 2 studies in the residential/commercial areas of Libby, and studies by W. R Grace) strongly support the conclusion that human activities that disturb potential source materials can result in elevated concentrations of asbestos fibers in the breathing zone of residents and workers.

5.        Fiber Concentrations in Air are of Human Health Concern (Risk Characterization)

*Exceedences of OSHA Standard*

The Occupational Safety and health Administration (OSHA) has established two occupational standards for exposure of workers: an 8-hour time-weighted average (TWA) value of 0.1 f/cc, and a short-term exposure limit (STEL) of 1 f/cc. As shown in Table 8, a number of personal air samples collected from residential or commercial locations (mainly those associated with active disturbance of vermiculite) exceed one or both of these standards.

**Table 8: Exceedences of OSHA Standards**

| Activity | TWA Exceedance Frequency (a) | | STEL Exceedance Frequency | |
|---|---|---|---|---|
| | PCM | PCME-asb | PCM | PCME-asb |
| Routine | 0 / 9 | 1 / 5 | 0/9 | 0/5 |
| Active cleaning | 1/122 | 0/80 | 4/125 | 0/83 |
| Simulated remodeling | 2/20 | 2/20 | 3/20 | 4/20 |
| Rototilling | 0/5 | 0/5 | 0/5 | 0/5 |

(a) All concentration values adjusted to represent an 8-hour average ($C_8 = C_t * t/8$)

It is important to recognize that occupational exposure standards for asbestos are not generally applicable or protective for residents or workers in non-asbestos environments because occupational standards are intended to protect individuals who **a)** are fully aware of the hazards of the occupational environment, **b)** have specific training and access to protective equipment such as respirators and/or protective clothing and, **c)** actively participate in medical monitoring (USEPA 1995). None of these conditions apply to residents or to workers at typical commercial establishments. Thus, simple compliance with the OSHA standards is not evidence that exposure levels are acceptable in a home or in a non-asbestos workplace. Indeed, risks to residents or workers occur at exposure levels substantially below the OSHA workplace standards, as discussed below.

*Screening Level Cancer Risk Estimates*

A number of alternative methods have been developed for estimating the risk of lung cancer and/or mesothelioma in humans from inhalation of asbestos fibers. Risk models developed by USEPA (1986), NIOSH (Stayner et al. 1997), and NRC (1984) all take the following form:

Risk = Concentration (PCM f/cc) · Slope factor (risk per PCM f/cc)

The slope factors derived by these different groups are presented below:

**Table 9: Inhalation Slope Factors for Asbestos**

| Source | Slope factor (Risk per PCM f/cc) |
|---|---|
| EPA (1986) | 0.23 |
| Stayner et al. (1997) | 0.078 |
| NRC (1984) | 0.154 |

These slope factors are intended to apply to long-term average concentrations rather than peak concentrations that occur during short-term activities, so application of the basic risk model to the evaluation of intermittent exposures requires a term to account for the less than continuous nature of the exposure:

Risk = Concentration (PCM f/cc) · TWF · Slope Factor (risk per PCM f/cc)

where:

TWF = Time-weighting factor to account for less-than-lifetime exposure via the activity being evaluated. For example, if an activity were performed for 1 hour per day, three days per week for 50 years, the TWF would be (1/24)·(3/7)·(50/70) = 0.0128.

EPA is in the process of obtaining site-specific data on the likely exposure frequency and duration (TWF) for the various scenarios of potential concern, but plausible screening level exposure frequencies and durations are shown in Table 7. These values are generally similar to the reasonable maximum exposure (RME) assumptions commonly employed for residents and workers at other Superfund sites, except that the exposure duration was assumed to be somewhat higher than the normal default (25 years for workers and 30 years for residents) due to greater stability of the Libby community.

**Table10: Screening Level Exposure Parameters for Residential/Worker Exposures**

| Activity | Exposure Assumptions | | | |
|---|---|---|---|---|
| | hrs/dy | days/yr | yrs | TWF |
| Scenario 1 (Routine activities by a resident)) | 16 | 350 | 40 | 0.3653 |
| Scenario 2 (Active cleaning by a resident) | 2 | 50 | 40 | 0.0065 |
| Scenario 3a (Extensive contact with vermiculite by a contractor) | 4 | 30 | 40 | 0.0078 |
| Scenario 3b (Limited contact with vermiculite by a resident) | 1 | 12 | 40 | 0.0008 |
| Scenario 4 (Rototilling a home garden by a resident) | 2 | 8 | 40 | 0.0010 |

Because detection limits for asbestos were rather high in some air samples (due to a small volume of air and/or a small number of grid openings counted), all non-detect values were evaluated by assigning a value of zero. Note that this approach is likely to underestimate the true level of risk, although the magnitude of the underestimation cannot be quantified.

The screening level risk estimates are shown in Figure 3. The results in the upper panel are based on the average values across samples within a Scenario, while the lower panel shows the results for the maximum value within a Scenario. Thus, the upper panel yields an overview of the risks that may be "typical" for the scenarios evaluated, while the lower panel reflects the risks at the most contaminated sub-locations.

When exposure is assessed based on PCM (open symbols), the estimated risks based on both average and/or maximum approach or exceed the upper bound of EPA's usual risk range (a value of 1E-04, as shown by the horizontal dashed lines) in all cases except Scenario 4 (rototilling). When exposure is assessed by TEM (PCME-abs) (solid symbols), results are generally similar or higher, except for Scenario 2. In this case, predicted risks are lower by PCME-asb than by PCM. As noted above, this is because PCM measurements for Scenario 2 capture a number of fiber structures that are not asbestos, leading to an overestimation of exposure.

In interpreting these risk estimates, it is important to stress that the values are screening level, both because of uncertainties in the concentration term and in the exposure assumptions. Nevertheless, the results strongly indicate that exposure to fibers released to air by disturbance of contaminated source materials may be of substantial human health concern. Further, even though screening level calculations generally tend to be conservative, there are several reasons to think that the risk values above may tend to underestimate true risk, as discussed below.

*These Risk Estimates Could Be Too Low*

Several factors suggest the risk estimates presented above may be too low and that actual risks may be higher.

1) All calculations of risk presented above treated non-detects as if they were zero. However, this is very unlikely to be the case. Indeed, even if the number of TEM fibers observed in a sample is zero, there is a 5% chance the true number could be as high as 3. Thus, many samples where no fibers were detected (i.e., were non-detect) could have 1-3 fibers present, and the associated concentrations would be greater than zero. EPA guidance for risk calculations at Superfund sites specifies that non-detects should normally be evaluated by assuming a concentration value equal to 1/2 the detection limit. This practice was not followed in the screening level calculations above because detection limits (sensitivity values) were sufficiently high in some samples that risks calculated in this way would be significantly influenced by the non-detects, with a contribution to risk of 1E-05 to 4E-05 for some scenarios. Nevertheless, it is very likely that at least some samples that were treated as non-detects did actually contain PCM or PCME fibers, and evaluating them by assigning a concentration of zero caused an underestimate of the true concentration and true risk values.

2) Calculations of risk based on PCM or PCME-asb consider only a fraction of the total fibers present. Figure 4 summarizes data on the size (thickness and length) of Libby-class amphibole fibers detected in air samples from various locations in Libby. As seen, fiber lengths range from less than 1 um to more than 20 um, and fiber thicknesses range from around 0.1 to 1 um. Libby amphibole class fibers that are in the PCME "bin" (thicker than 0.25 um, longer than 5 um, and with an aspect ratio of 3:1 or greater) include only about one third of the total fibers observed. Even though recent studies support the view that asbestos toxicity does depend on fiber thickness and length (see below), the likelihood that Libby amphibole fiber toxicity is confined strictly to fibers in this regulatory size fraction is neither toxicologically sound nor supported by the available health data from Libby (MacDonald et al., 1986, Amandus et al.. 1987a,b,c; ATSDR 2001).

3) An alternative risk model is currently under development by the USEPA (1999). This risk model seeks to account for apparent differences in lung cancer risk as a function of fiber size and type. Although this risk model has not yet been peer reviewed, it is potentially important because fiber toxicity is expected to vary as a function of fiber length, with longer fibers displaying greater toxicity than shorter fibers. Thus, it is possible that actual cancer risks presented here may be underestimated using the slope factors developed by EPA, NRC, and/or NIOSH, since these slope factors are based mainly on studies where exposures to long fibers (> 10 um) may not have been as likely as at Libby.

4) Additionally, EPA has no methods available for calculating the risk of non-cancer health effects due to asbestos exposure, despite extremely elevated incidence of asbestosis mortality in the community of Libby (ATSDR, 2000). Libby residents have 40-60 times the national rate of asbestosis (placing Lincoln county, Montana, among the top ten counties for this condition in the country). The cancer risks estimated above do not address this condition or other non-malignant asbestos-related conditions (i.e., asbestos-related pleural disease) recently found to be occurring among a large number of Libby residents. Asbestos exposure, as evidenced by non-malignant chest radiographic abnormalities, is also associated with an increased lifetime risk of lung cancer, especially among smokers. The models used to estimate cancer risk do not account for increased risk as a result of prior lung disease. Thus risks in Libby may be significantly higher as a result of historical exposure.

Taken together, these considerations all support the conclusion that risk estimates, derived as above, may substantially underestimate the true public health risk to area residents and workers from on-going exposures to asbestos contamination.

## V CONCLUSIONS

Asbestos contamination exists in a number of potential source materials at multiple locations in and around the residential and commercial area of Libby. These potential source materials include yard soil, garden soil, driveway material, waste piles, indoor dust, and vermiculite insulation. If these contaminated sources are disturbed by human activities, fibers are likely to be released to air. The concentration levels released to air depend on the concentration of fibers in the source material and on the nature of the disturbance. Risks are proportional to the concentration of fibers in air and the frequency and duration of exposure. While data are not yet sufficient to perform reliable human-health risk evaluations for all sources and all types of disturbance, it is apparent that releases of fiber concentrations higher than OSHA standards may occur in some cases (mainly those associated with active disturbance of vermiculite), and that screening-level estimates of lifetime excess cancer risk can exceed the upper-bound risk range of 1E-04 usually used by EPA for residents under a variety of exposure scenarios. The occurrence of non-occupational asbestos-related disease that has been observed among Libby residents is extremely unusual, and has not been associated with asbestos mines elsewhere, suggesting either very high and prolonged environmental exposures and/or increased toxicity of this form of amphibole asbestos. On this basis, I recommend that steps be taken to further identify, quantify, minimize and/or eliminate pathways of human exposure to amphibole asbestos in the residential areas of Libby.

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